MANITOBA CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

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Canada

MANITOBA

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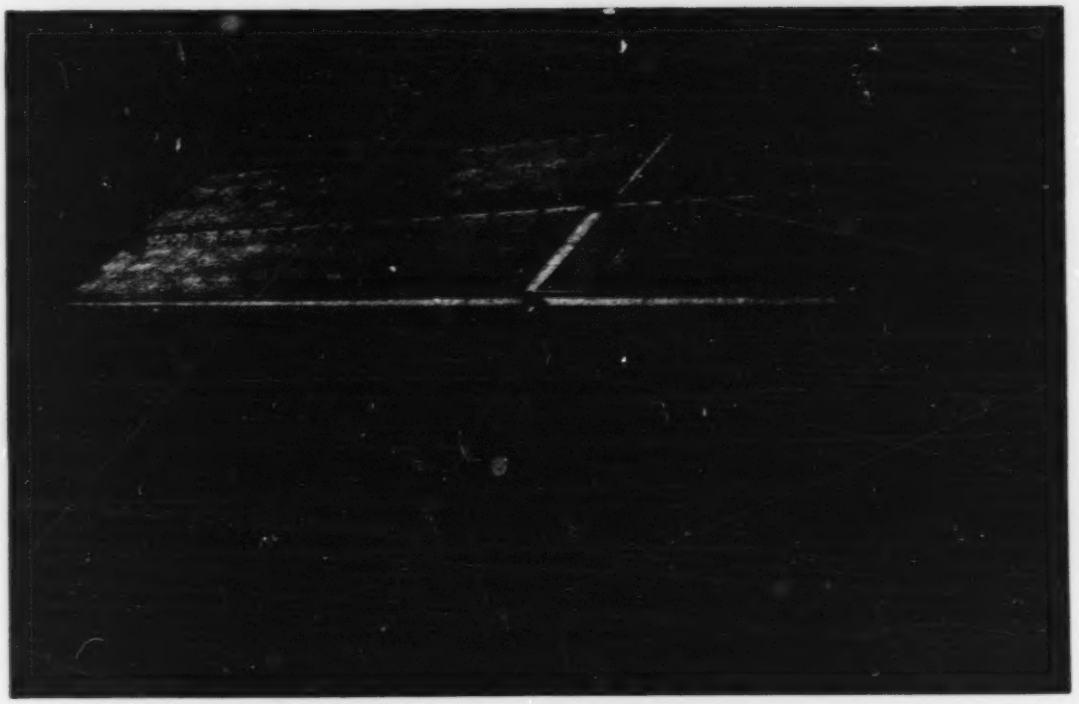

SOLAR HEATED SWIMMING POOL

DELORAINE, MANITOBA

MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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EXECUTIVE SUMMARY

Swimming pool heating has been demonstrated to be one of the most economic applications for solar energy. However, there has been a lack of reliable information covering community pool operations, particularly those located in the cold climate of the Canadian prairie.

This report describes the design and the monitoring results for the first season of operation of an active solar pool heating system installed at Deloraine, Manitoba.

E. J. Faraci and Associates of Winnipeg were responsible for the design and for analysis of the monitoring data. The project was funded under the Manitoba/Canada Energy Demonstration Agreement.

SYSTEM DESCRIPTION

The active solar system consists of 48 plastic collectors linked in four banks, angled at 65 degrees to the horizontal, for a total of 143 square meters. The pool holds 507,000 litres with a surface area of 214 square meters.

When the designated pool temperature is reached, after sufficient solar heat collection, the amount of water flowing through the collectors is reduced and diverted through a water-to-water heat exchanger for heating shower water. Heated shower water is stored in a 1,840 litre tank.

The pool is operated from June to September and is devoid of back-up water heating systems. A pool cover is used during off hours.

RESULTS AND CONCLUSIONS

1. The economic analysis based on the results of monitoring the first year of operation indicates savings of 352 GJ of propane, a standard heating fuel in this area. Since the pool was not fully utilized in its first season of operation greater savings are expected.

2. Solar heated swimming pool installations will integrate well with the attitudes and requirements of Manitoba communities.

3. The results of the monitoring program showed that pool temperatures were maintained within an acceptable range, considering the active swimming pool program maintained by the Deloraine Community. Operating energy costs were minimal.

4. The benefits of using a swimming pool cover were demonstrated, and scrupulous use of the cover was shown to be the most significant technique for improving pool performance during the second year of operation.

5. A collector area to pool surface area ratio of 0.5 is valid for Manitoban installations, provided a pool cover is used. If the solar system is also used to heat shower water, this ratio must be increased in accordance with the increased heating load, eg. to 0.75.

6. The solar system should be integrated, at least for preheating, with the shower water system. Using the solar system without auxiliary shower water heating may compromise the level of performance. The installation of a supplemental heating system would remain the decision of the community. A conventional hot water tank may be retrofit easily and it is recommended that an installation be originally designed without supplemental heating.

7. Although an automatic control system would provide an optimum interface between pool heating and shower water heating, the Deloraine project demonstrated that manual control was practical.

RÉSUMÉ ADMINISTRATIF

Il a été démontré que le chauffage des piscines est l'une des applications les plus économiques de l'énergie solaire. Toutefois, on manque d'information sérieuse concernant les fonctionnement des piscines communautaires - et particulièrement lorsque ces piscines se trouvent dans les Prairies canadiennes au climat froid.

Dans ce rapport, on fait la description d'un système de chauffage utilisant l'énergie solaire dans une piscine de Deloraine (Manitoba) et on donne les résultats obtenus au cours de la première saison de fonctionnement.

La maison "E.J. Faraci and Associates" de Winnipeg a été chargée de faire les plans et d'analyser les résultats obtenus. C'est l'entente Manitoba/Canada sur la démonstration de l'énergie qui a permis le financement du projet.

DESCRIPTION DU SYSTÈME

Le système d'énergie solaire est composé de 48 collecteurs en plastique, lesquels sont reliés en quatre sections inclinées à 65 degrés par rapport à l'horizontale et occupant une superficie de 143 mètres carrés. La piscine contient 507 000 litres; elle a une surface de 214 mètres carrés.

Quand la température voulue est atteinte avec suffisamment d'énergie solaire, la quantité d'eau qui circule dans les collecteurs est réduite et elle est détournée vers un échangeur thermique à circulation d'eau qui fait chauffer l'eau des douches. L'eau chaude des douches est emmagasinée dans un réservoir de 1 840 litres.

La piscine fonctionne de juin à septembre et n'est pas munie de systèmes auxiliaires pour chauffer l'eau. On couvre la piscine en dehors des heures d'ouverture.

RESULTATS ET CONCLUSION

1. Basée sur les résultats obtenus au cours de la première année de fonctionnement, l'analyse économique fait ressortir une économie de 352 GJ de propane dont on se sert couramment dans la région pour le chauffage. Etant donné que la piscine n'a pas été utilisée à pleine capacité pendant sa première saison de fonctionnement, on envisage une économie plus grande encore.

2. Les installations de chauffage solaire des piscines seront bien acceptées par les communautés manitobaines et répondront bien à leurs besoins.

3. Les résultats du programme de contrôle font ressortir que l'eau de la piscine était maintenue à des températures adéquates, compte tenu de l'activité des programmes de natation de la communauté de Deloraine. Les coûts de fonctionnement relatifs à l'énergie étaient minimes.

4. On a démontré qu'il était avantageux de couvrir la piscine et que cet usage suivi consciencieusement était la technique la plus efficace pour améliorer le rendement de la piscine pendant la deuxième année de fonctionnement.

5. Un rapport de 0,5 entre la surface des collecteurs et la surface de la piscine est valable pour les installations du Manitoba à condition de couvrir les piscines. Si on se sert aussi du système solaire pour chauffer l'eau des douches, il faudra augmenter cette proportion - jusqu'à 0,75 par exemple, conformément aux besoins thermiques accrus.

6. Il faudrait incorporer le système de chauffage solaire au système de chauffage des douches, tout au moins pour le chauffage préliminaire. On risque de compromettre le taux de rendement si on utilise le système de chauffage solaire sans chauffage auxiliaire de l'eau des douches. C'est à la communauté que reviendra la décision de faire installer un système de chauffage supplémentaire. Un réservoir d'eau chaude ordinaire est facilement transformable et il est suggéré qu'à l'origine une installation soit conçue sans y prévoir de chauffage supplémentaire.

7. Bien qu'un système de contrôle automatique permettre la synchronisation optimale du chauffage de la piscine et des douches, le projet de Deloraine a prouvé que le contrôle manuel était possible.

INTRODUCTION

E.J. Faraci and Associates, a Winnipeg mechanical engineering consulting firm, recently designed a solar energy system for the Deloraine Municipal Pool that would provide heat for both the pool and the shower hot water. Construction was completed and the facility operated from June 10, 1981 to August 31, 1981.

During the conceptual design phase of the project, it was quickly realized that reliable design criteria for "community" size swimming pools (particularly for Canadian prairie installations) was not available. Although solar swimming pool heating has been accepted by the industry as one of the most viable applications for solar energy, most the information is geared to residential sized pools (where pool temperatures may not be as important as for a community pool with organized sports programs) in areas with significantly different climatic and solar conditions than Manitoba.

Procedures for calculating the monthly solar energy collected by a given type and area of collector are well established and provide the designer with an estimate (eg. F-Chart) of the solar contribution. However the critical component of any solar system design is determining the actual heating load that will be imposed on the system. For a swimming pool, this would represent a complex, hour by hour heat loss analysis that is very dependant on the climatic conditions (eg. ambient temperature, wind, vapour pressure). Obviously, a detailed computer simulation could not be justified within the scope of the typical swimming pool design projects and "rules of thumb" for sizing swimming pool systems have been adopted. (eg. collector area = 50% pool surface area).

The most practical method of establishing the performance of a particular solar swimming pool system is to actually monitor the pool temperature throughout the season. Although information generated by such a monitoring program would not benefit the operation of the installed system, it would assist with optimizing the design of future Manitoba community solar pools.

Another important variable in the performance of solar pool systems is the use of pool covers to reduce the evaporative and conductive heat loss during non-use hours. Although the suppliers of swimming pool equipment will recommend the use of a pool cover, the significance of this conservation technique is seldom quantified.

PROJECT OBJECTIVES

1. To record the daily, weekly and monthly pool temperature profiles for the solar heated, Deloraine community swimming pool during the first season of operation.

2. To record the corresponding ambient air temperature so that the pool performance can be related to average climatological conditions in Manitoba.

3. To compare the performance of the system with and without a swimming pool cover.

4. To evaluate the cost effectiveness of intergrating the domestic hot water with the solar system. (The Deloraine system utilizes solar hot water heating for the shower water. The system can be operated in a dual usage or pool only mode.)

5. To establish pool heat loss data and associated solar system design criteria for "community" sized outdoor swimming pools in Manitoba.

SOLAR SYSTEM DESCRIPTION

A schematic of the Deloraine swimming pool solar system is shown in Figure 1. The system was designed to accommodate both the pool water and the domestic shower water load. The original design package specified automatic controls that would switch from the

"pool" mode to the "shower" mode after the set pool temperature had been reached. It had been acknowledged by the design that supplementary hot water heating could be required to maintain the shower water delivery temperature at an acceptable level.

The "as built" system did not incorporate the automatic control system nor was supplemental hot water heating installed. (The community objective was to operate the facility without auxillary fuel.) The manual control sequence eventually adopted by the pool staff reflected the higher priority given to shower water heating. The pool users preferred the shower water at 35°C (95°F) and the pool temperature at 25°C (77°F) than for example, the pool temperature at 27°C (80°F) with the shower water at 25°C (77°F).

As shown by the schematic, pool water is circulated through the solar collectors during the pool heating mode and returned to the pool at an elevated temperature. To heat the shower water, the pool water by-passes the solar loop and the return from the collector is directed through a heat exchanger installed in the hot water storage tank. The heat exchanger is required to separate the chlorinated pool water from the domestic shower water. The shower water storage tank was 1,840 l (405 gal.).

The solar collector panels specified were 1,219 mm (4 ft.) by 2,438 mm (8 ft.), "Thermo Solar" medium temperature with single glazing manufactured by Petro-Sun Inc. The collector efficiency curve is shown by Figure 5. Forty-eight panels were installed with a gross collector area of 143 m^2 (1,536 $ft.^2$). Pool volume was 507,000 litres (112,000 Imp.gal.) with a surface area of 214 m^2 (2,310 $ft.^2$). The resultant design collector to pool surface area ratio was 0.67.

MONITORING PROCEDURE

A dual pen chart recorder (Photo 3) with thermocouple inputs was used to monitor pool temperature and collector return temperature between June 10 (start-up) and July 24. Between July 24 and pool closing, the pool temperature probe was relocated and used to monitor the temperature of the hot water storage tank. Although not used for automatic control, a differential temperature controller had been installed as part of the package. This controller had five temperature monitoring channels which were used to measure pool temperature, collector temperature, collector return temperature, hot water storage temperature and outdoor ambient temperature.

The pool manager and staff regularly recorded the output from this multi-channel temperature monitor (five times/day). This data supplemented the chart recording and was used to develop the daily and monthly pool temperature profiles. (Figure 2 and Figure 6) The ambient outdoor air temperature was also supplemented with data provided by Environment Canada for the Town of Deloraine.

RESULTS/ANALYSIS

1. The pool temperature profile over the first season of operation (June, July and August) and the corresponding mean, outdoor air temperatures are summarized in Figure 2. A detailed record of pool operation, pool temperatures and weather conditions are recorded on Figure 6. An average pool temperature of 25.5°C (78°F) was maintained through July and August with full operation of the solar system. The lowest daytime pool temperature recorded during this period was 23°C (73°F) and the highest temperature recorded was 28°C (83°F). This level of pool "performance", maintained without the operation of an auxillary pool heating system, was acceptable to the pool users.

2. A conventional propane swimming pool heater generally would be set to maintain the pool temperature at 26.6°C (80°F), approximately one degree higher than the recorded July/August mean pool temperature of 25.5°C (79°F). The energy associated with increasing the average pool temperature by 1°C during July and August was calculated based on pool heat loss equations[1] and the recorded mean ambient temperatures. An estimated 103 gigajoules (100×10^6 Btu.) over the three month summer operation would have been required to supplement the solar system if a constant pool temperature of 26.6°C (80°F) has been maintained. The energy cost of this one degree improvement in pool "performance" was estimated at $930.00 (based on the 1982 rate for propane (23.9¢/litre), and a boiler efficiency of 70% and assuming that a pool cover was not used).

3. The performance of the solar heating system during pool start-up is shown in Figure 3. Although the pool was opened early June, the solar system was not in full operation and "start-up" performance has not been recorded. However, it had been necessary for the pool staff to drain the pool during the

third week of operation and the second start-up condition was monitored from June 25 to July 1. A "warm-up" period of five days was required to raise the pool water from 16°C (60°F) to 26°C (78°F). Conventional systems generally are sized to raise the pool temperature to 27°C (80°F) within two days. This would represent an energy requirement for the Deloraine pool of approximately 23 gigajoules or a cost of $200.00. Obviously the "warm-up" energy during the first week of June would have been slightly greater due to the lower temperature of water used to fill the pool. If it was assumed that two start-up periods were required each summer (ie. one drain required during the season), the energy requirement would approach 50 gigajoules estimated at $615.00/year.

The net energy contribution of the solar system during start-up was established using a recognized computer analysis[2] and used to predict the pool temperature rise if neither solar or auxillary heating had been installed. (Also shown in Figure 3.)

4. From July 17 to the end of August, the solar system was also used to heat domestic shower water. The mode of operation was to switch to "hot water heating" for a two or three hour period during mid-day. This was generally sufficient to provide hot water for the remainder of the day. Sometimes it was necessary to switch back to the hot water mode during the latter part of the day. The hot water consumption was recorded and an average daily usage of 2,700 l (600 gal.) established. The solar energy contribution to shower water heating was calculated based on cold water supply temperature of 14°C (57°F) and a system performance as represented by Figure 4. A net solar contribution of 300 megajoules /day with a projecting saving of $345.00 over a three month operation was estimated.

The switch from "pool" only to both "pool" and "hot water" heating did not significantly affect the pool temperatures. An average reduction of 1/4°C (1/2°F) was recorded. The shower hot water energy requirement was kept to a minimum through the use of automatic shut off valves at each shower head and the installation of a cold water mixing valve in the shower water supply line. The mixing valve maintained a maximum shower supply temperature of 32°C (90°F), very adequate for showering after leaving a pool at 26°C (78°F). As a result, the hot water energy requirement of the Deloraine pool was lower than community pools constructed before attention was given to energy conservation. One of the indirect benefits of any solar installation is the conservation effort necessary to maximize the effect of the solar energy contribution. (eg. solar blankets, regulated hot water usage)

5. The use of a swimming pool cover during non-use periods can significantly reduce the heat losses from a pool. Although a pool cover was not purchased and installed until August 10, the benefits were clearly demonstrated by the temperature monitoring. Before the pool cover usage, an average pool temperature drop during the evening of 1.84°C (3.32°F) was recorded (June 26 to August 9). For a pool volume of 507,000 litres (112,000 gal.) and surface area of 214 m^2 (2,300 $ft.^2$), this temperature drop represents an average "night-time" heat loss from the pool of 17 MJ/m^3 per day (1,600 $Btu/ft.^2$). From August 10 to the end of the season, the average night pool temperature drop was reduced to 1.1°C (2°F) representing a heat loss of 10 MJ/m^2 per day (970 $Btu/ft.^2$). Based on 214 m^2, a conservation of 1.5 gigajoules per day was established and, over a three month season, would suggest a saving (assuming that the heat loss had been made up using a 70% efficient propane heater) of $1,700.00/year.

6. Approximately 2/3 of the solar energy collected during full operation of the system (from July 17) was used directly for pool water heating. The remainder was absorbed by the shower water heating load. Although the design collector area to pool surface area ratio for this solar system was $\frac{143\ m^3}{214\ m^2} = 0.67$, the effective ratio for only pool heating would be approximately $\frac{2/3 \times 143}{214} = 0.45$ (slightly less than the minimum recommended "rule of thumb" for pool solar systems). Although pool performance was acceptable, there was no excess solar energy (ie. pool temperatures significantly higher than 27°C). Performance of the system was borderline from July 17 to August 10 when the system also was used for shower water heating and the pool cover was not being used.

To maintain an average pool temperature of 27°C (80°F) without proper use of a pool cover, a collector to pool area ratio in excess of 1.0 would be required.

ECONOMIC REVIEW

The previous sections estimated energy savings associated with the individual components of a solar/conservation design. The following summarizes the net benefit of the "total" system based on a propane cost of 23.9¢/litre and a boiler efficiency of 70% (ie. $12.30 per gigajoule).

i) Solar energy contribution - pool heating

60 GJ @ $12.30 = $ 740

ii) Supplemental energy that would have been required to raise the monitored mean pool temperature of 25.5°C (78°F) to a 26.6°C (80°F) design condition

76 GJ @ $12.30 = $ 935

iii) Pool "warm-up" energy, assuming one drain down in mid-season

50 GJ @ $12.30 = $ 615

iv) Solar contribution - shower water heating

28 GJ @ $12.30 = $ 345

v) Pool cover energy saving

138 GJ @ $12.30 = $1,700

Net Benefit $4,335/year

Based on an installed system cost of $52,000 and a $5,000 credit for the installation of a propane heater, a simple payback of $\frac{\$52,000 - \$5,000}{\$4,335}$ = 11 years is suggested. Although somewhat high, it should be recognized that recent projections (Federal/Alberta Agreement) for fuel pricing show a doubling within four years. The payback becomes attractive!

The estimated savings in fuel are based on pool operation as monitored during the summer of 1981 and on 1982 fuel prices. This may not be representative of pool operation for an established facility. The estimated "energy" saving is believed conservative, as discussions with operators of similar pool facilities suggested annual energy costs exceeding $6,000.00/year.

Note: Maintenance had not been considered by the above analysis. The only method to establish a "real" maintenance cost is through accurate record keeping over a given period (eg. 10 years). However, the maintenance "debit" would be compensated by an energy conservation "credit" associated with the Deloraine operation and the above analysis should remain valid. (ie. Although maintenance cost consideration would have increased the calculated payback, the net energy contribution applied to the payback analysis was conservative when compared to pools designed without consideration for energy conservation.)

CONCLUSIONS/RECOMMENDATIONS

A solar swimming pool installation will integrate well with the attitudes and requirements of a Manitoba community. Pool "performance" cannot be compared directly to one designed with little consideration for energy consumption. A compromise may be required.

The results of the monitoring program showed that pool temperatures were maintained within an acceptable range and an active swimming pool program maintained by the Deloraine Community. Operating energy costs were minimal.

The benefit of using a swimming pool cover was demonstrated, and it's religious installation shown to be the most significant technique for improving pool performance during the second year of operation.

A collector area to pool surface area ratio of 0.5 is valid for Manitoban installations, provided a pool cover is used. If the solar system is also used to heat shower water, this ratio must be increased in accordance with the increased heating load. (eg. 0.75)

The solar system should be integrated, at least for preheating, with the shower water system. Using the solar system without auxillary shower water heating may compromise the level of performance. The installation of a supplemental heating system would remain the decision of the community. A conventional hot water tank may be retro-fit easily and it is recommended that an installation be originally designed without supplemental heating.

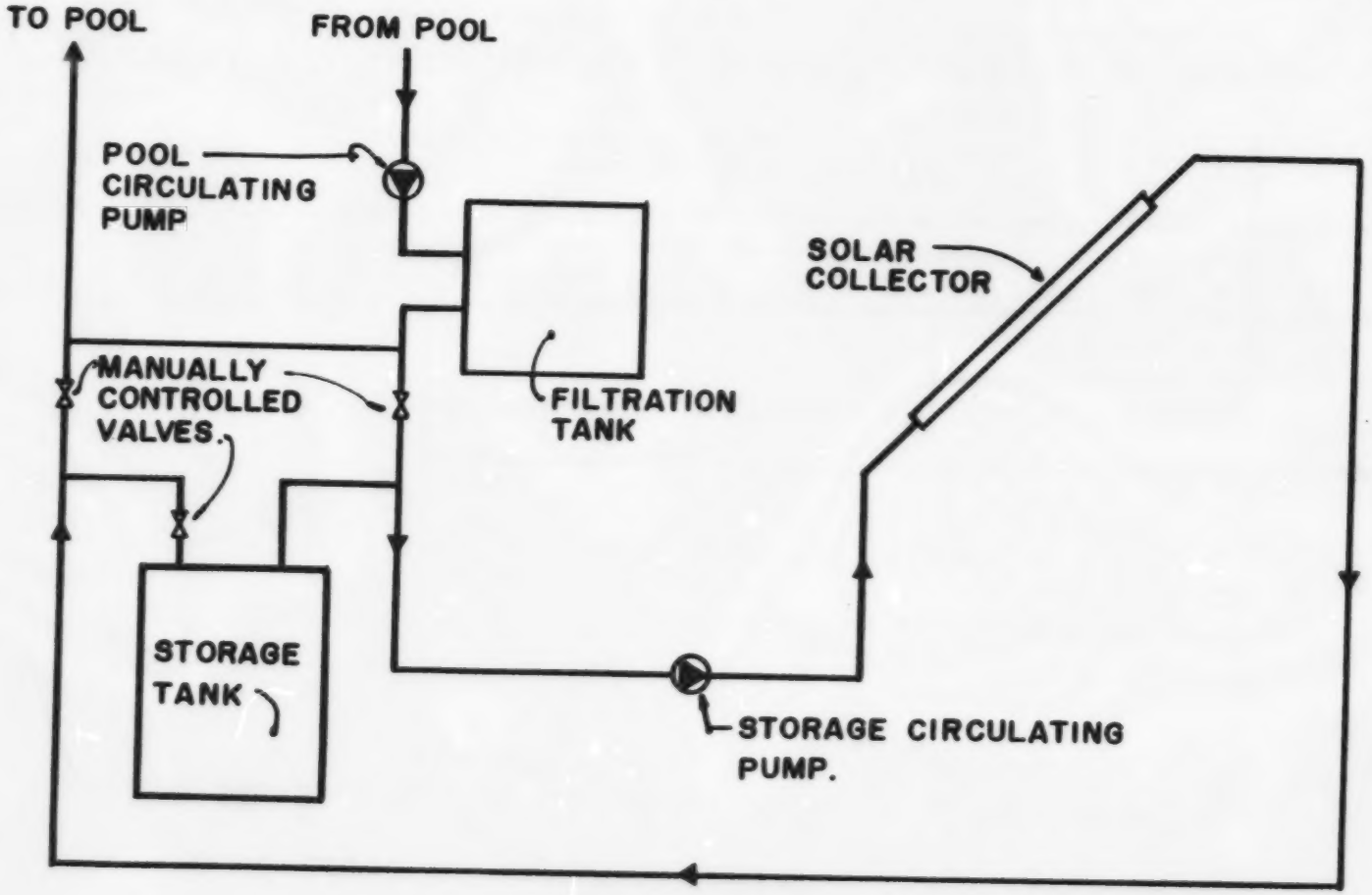
Although an automatic control system would provide an optimum interface between pool heating and shower water heating, the Deloraine project demonstrated that manual control was practical.

The psychological contribution of a solar pool installation is as significant as the direct solar energy input to reducing the energy cost of a community swimming pool.

REFERENCES

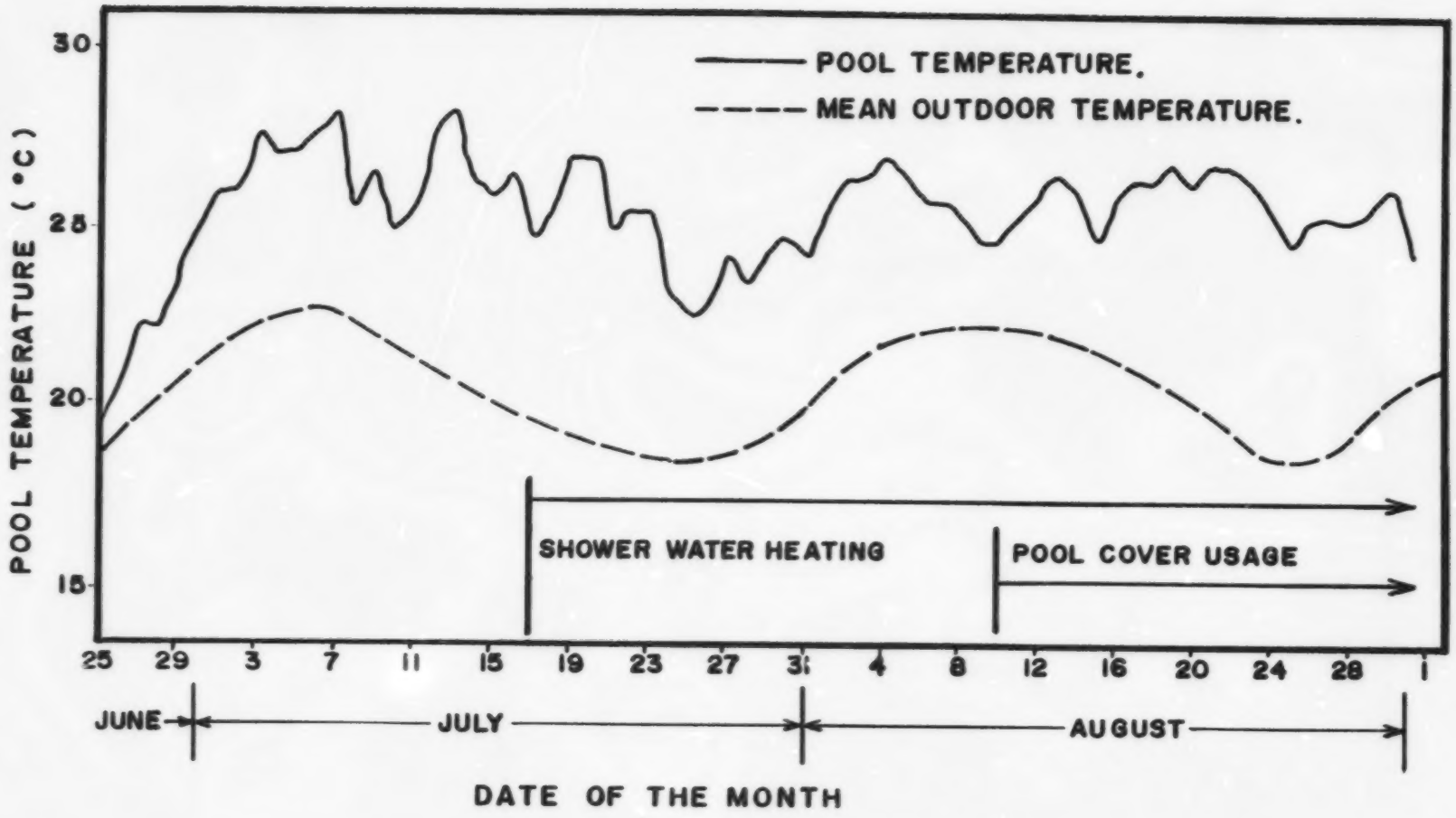
1. American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), 1980 Systems Handbook, Chapter 37.

2. Public Works Canada, Solar Programs Office. F-Chart Version 4.0, "A Design Program for Solar Heating Systems", Feb. 1981.



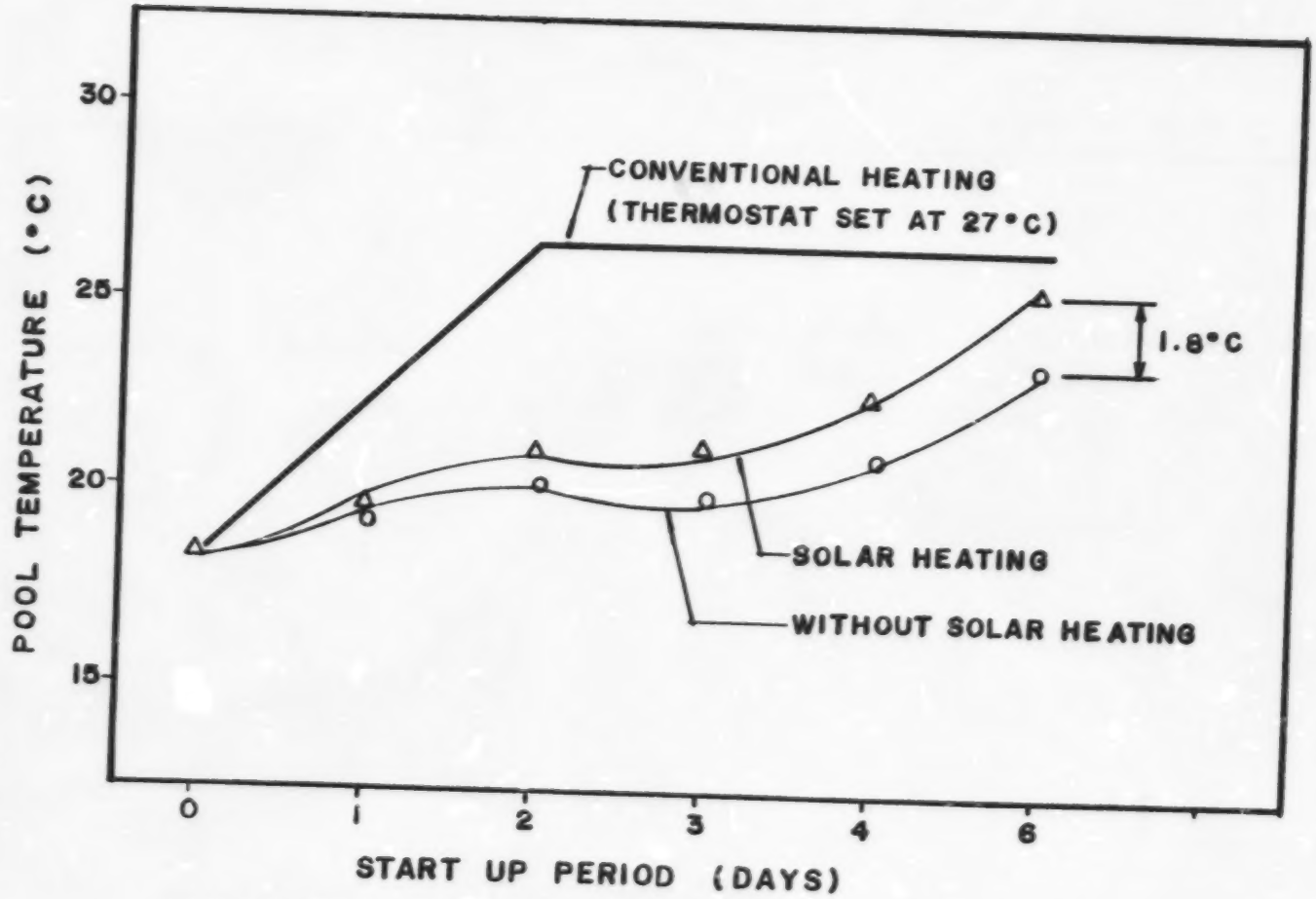
FLOW DIAGRAM OF DELORAINE MUNICIPAL POOL

FIGURE 1.



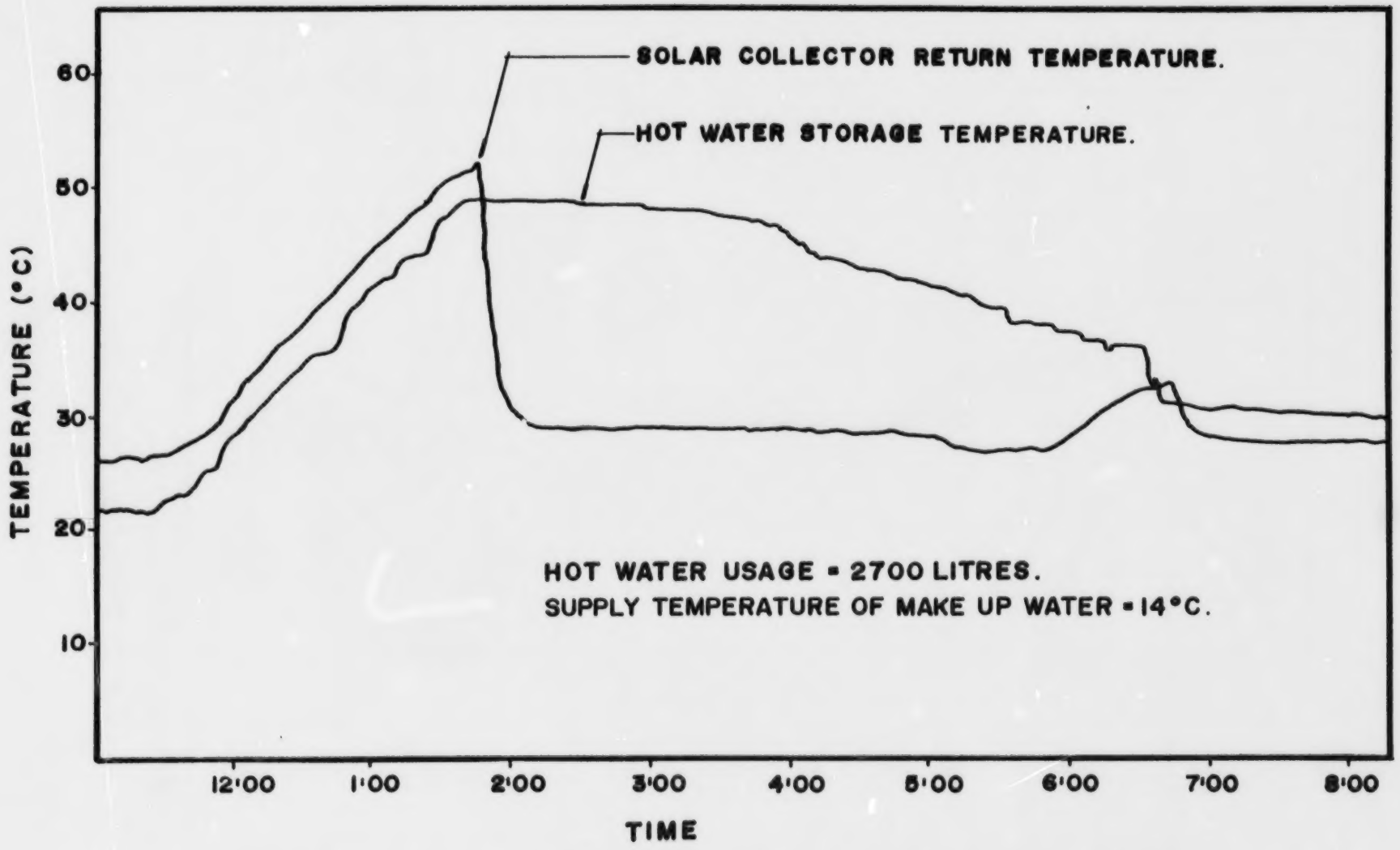
POOL TEMPERATURE PROFILE DURING OPERATION PERIOD

FIGURE 2



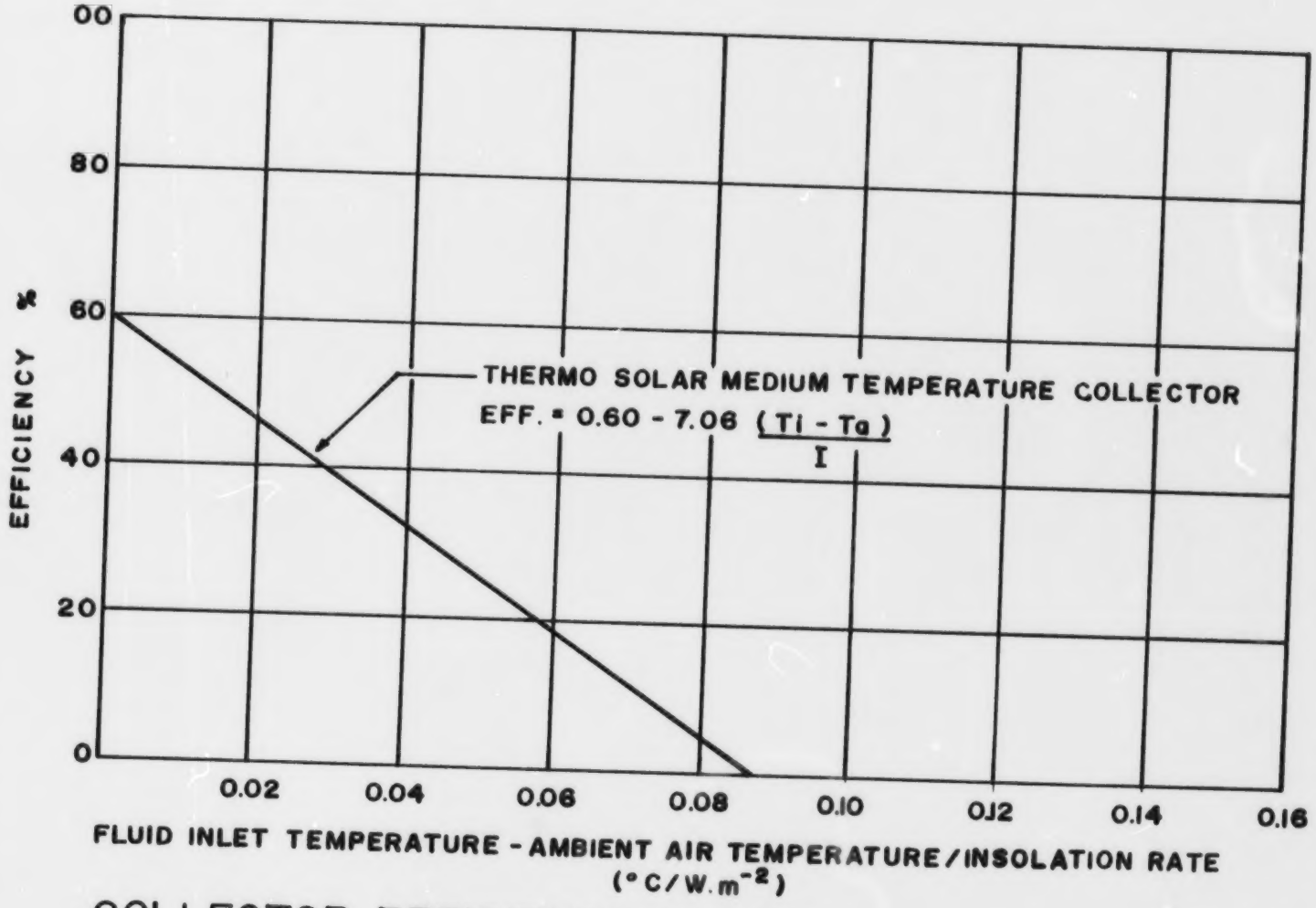
POOL TEMPERATURE RISE START-UP

FIGURE 3



SHOWER WATER TEMPERATURE PROFILE (JULY 29/81)

FIGURE 4.



COLLECTOR EFFICIENCY CURVE.

FIGURE. 5

| | | |

| | | |

	SUNNY	SUNNY	SUNNY	SUNNY	CLOUDY	SUNNY	SUNNY	SUNNY	SUNNY	SUNNY	CLOUDY	SUNNY	SUNNY	HAZY	SUNNY	CLOUDY	SUNNY	HAZY	SUNNY	SUNNY	RAINY	SUNNY	SUNNY	SUNNY	SUNNY	FOGGY	FOGGY	CLOUDY	CLOUDY	FOGGY	FOGGY	SUNNY	SUNNY	SUNNY	SUNNY	SUNNY	RAINY
0	24.0	25.0	24.5	31.5	31.5	28.5	27.0	27.0	29.0	30.5	24.5	26.0	29.0	24.5	25.0	29.5	34.0	28.0	34.0	26.0	20.0	25.0	28.5	30.0	30.0	27.0	31.0	27.5	18.5	25.0	23.5	25.5	26.0	26.0	29.5	32.5	13.5
5	14.5	17.5	18.5	23.8	25.5	20.8	18.5	20.0	21.0	23.0	20.5	20.5	20.5	19.0	16.0	22.0	23.0	20.5	25.5	19.5	15.5	16.0	21.0	21.5	25.0	20.5	23.5	23.0	17.5	21.0	19.0	20.0	19.0	19.5	23.0	26.0	13.0
	5.0	10.0	12.5	16.0	19.5	13.0	9.0	13.0	13.0	14.5	16.0	14.5	11.5	12.5	7.0	15.0	13.0	13.0	16.5	12.5	10.5	7.0	13.5	14.5	20.0	13.5	14.5	17.0	16.5	16.5	14.0	14.0	11.0	12.5	15.5	19.0	12.5

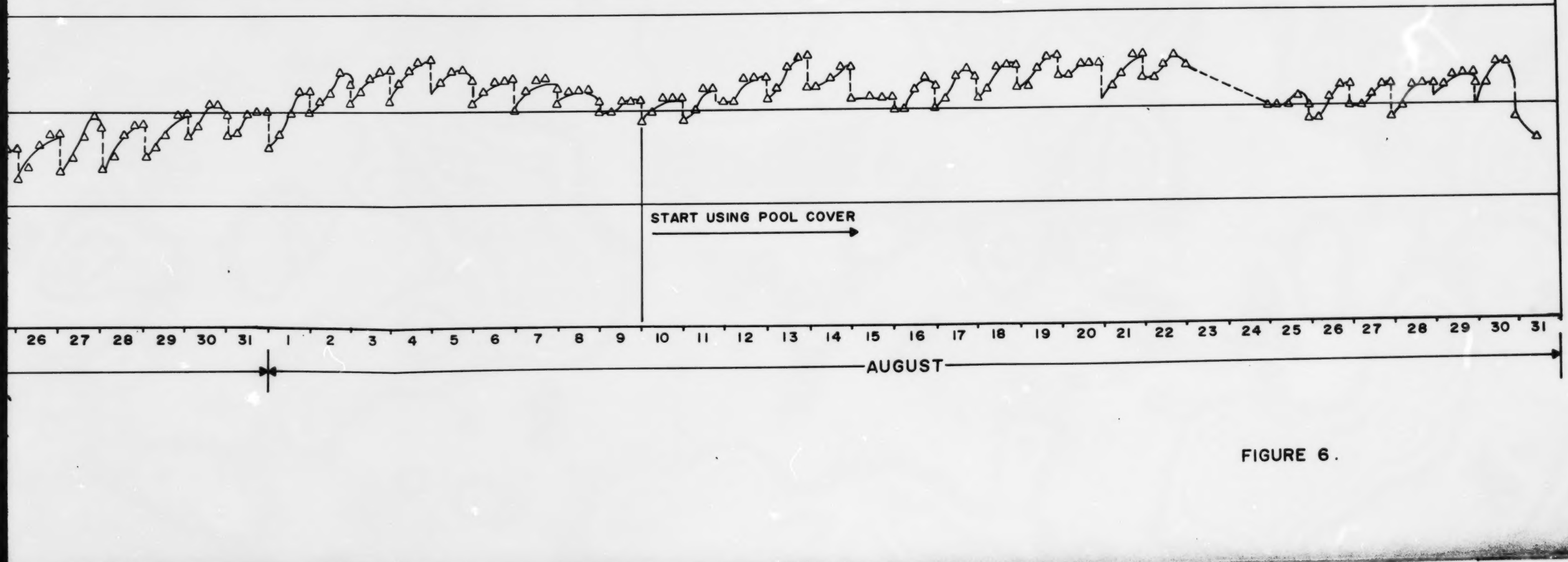


FIGURE 6.

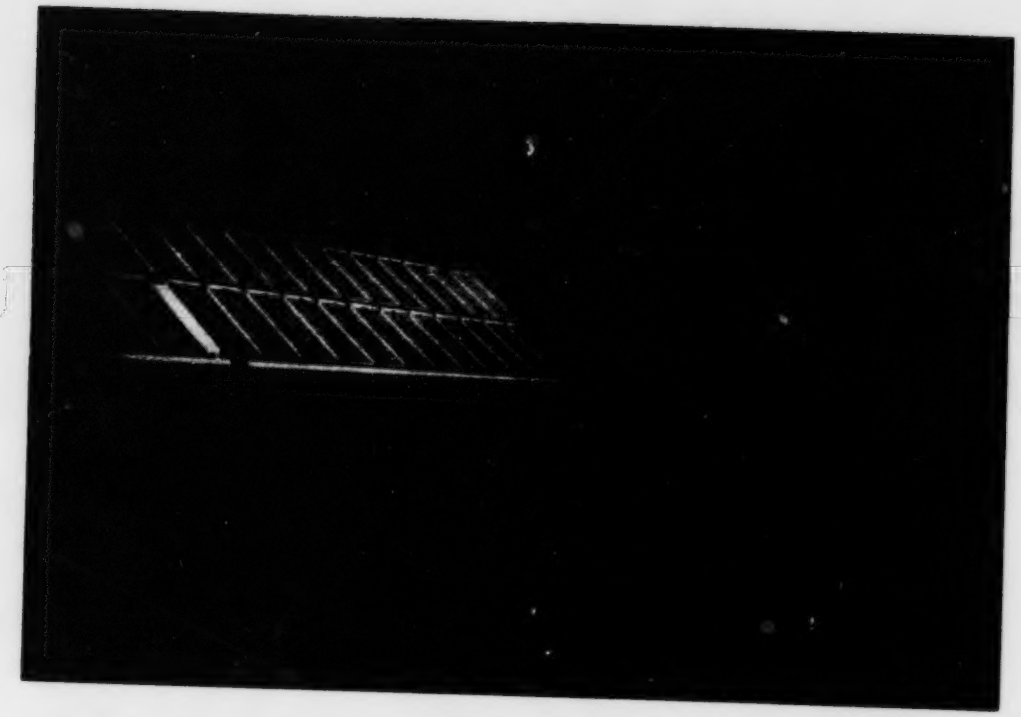


PHOTO 1 - DELORAINE SOLAR INSTALLATION.

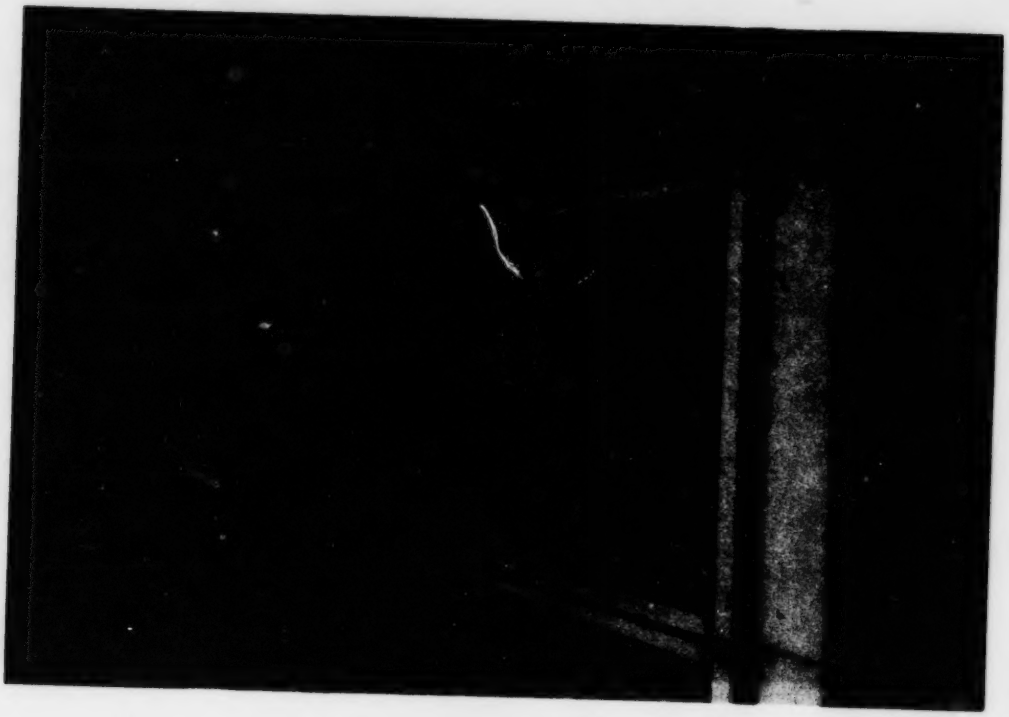


PHOTO 2 - CLOSE UP OF COLLECTOR PANELS.

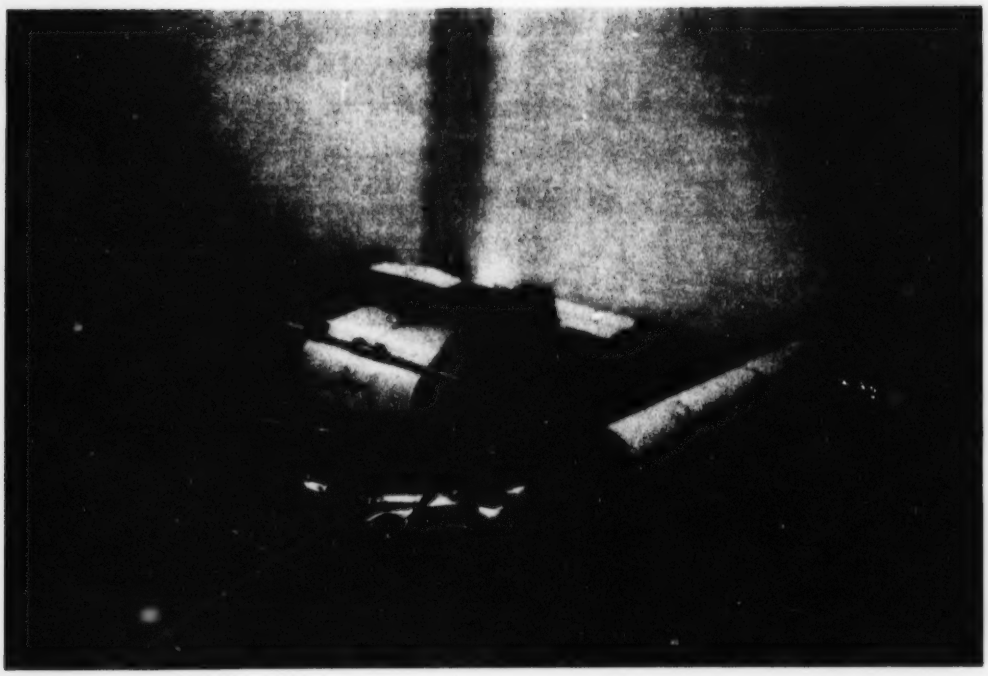


PHOTO 3 - TEMPERATURE MONITORING

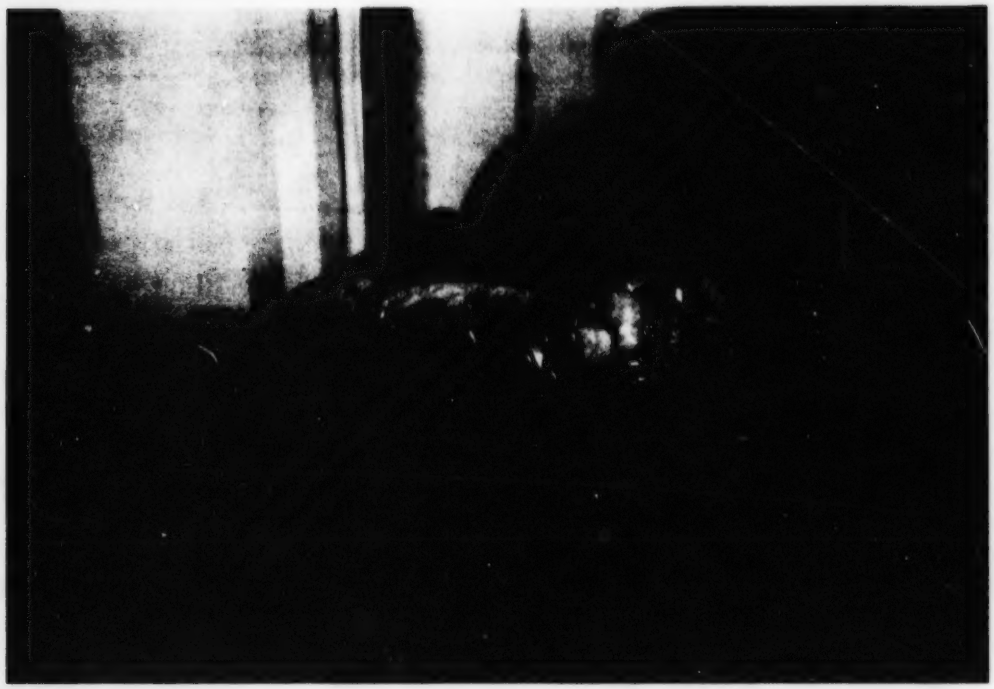


PHOTO 4 - INSULATED POOL TEMPERATURE
RECORDING PROBE (THERMOCOUPLE)

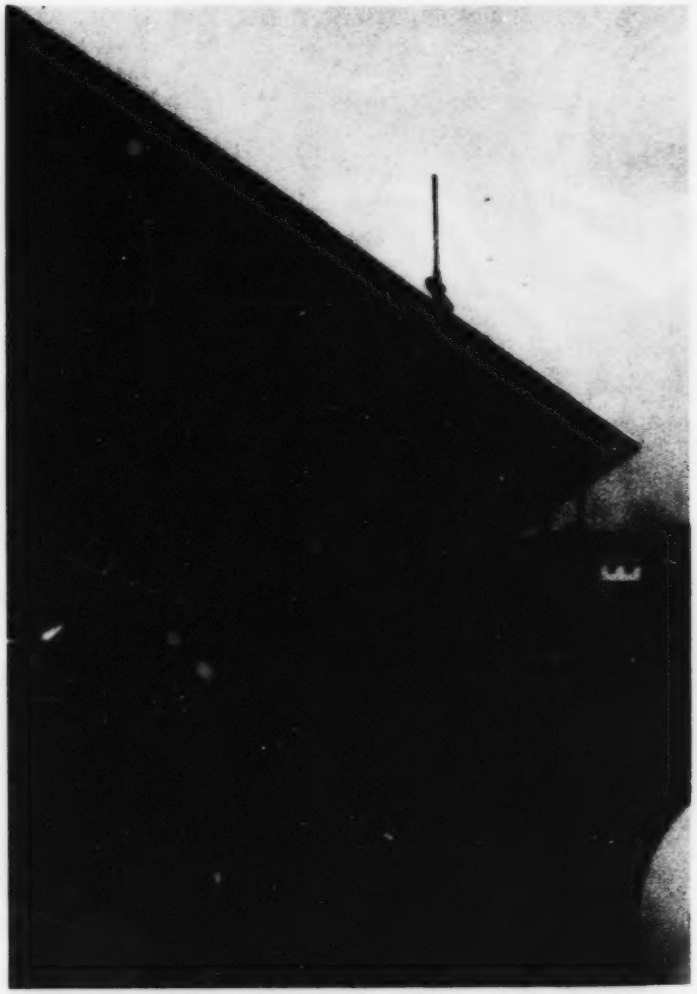


PHOTO 5

PANEL SUPPORT STRUCTURE.

PHOTO 6

MANUAL CONTROL VALVES.

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